EVALUATIONS OF A LOBLOLLY PINE SEEDLING SURVIVAL AND STORAGE PROBLEM ON THE SUMTER, CHATTAHOOCHEE, AND OCONEE NATIONAL FORESTS, 1983

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ABSTRACT

Deterioration of loblolly pine seedlings after short periods of cold storage and early plantation survival problems on the Sumter, Chattahoochee, and Oconee National Forests in the spring of 1983 were evaluated. The causes of seedling deterioration and death were determined to be physiological in origin, because seedlings were largely free of pest-caused injury. The likely cause of the problem is determined to be lack of full physiological dormancy due to late-season nitrogen fertilization and mild winter temperatures with heavy rains at W. W. Ashe Nursery, Brooklyn, Miss. Lack of dormancy resulted in rapid root deterioration of December- and January-lifted seedlings after short storage periods. Plantation failures and damaged, stored seedlings were reported on all Ranger Districts planting Georgia and South Carolina piedmont loblolly pine seed sources. Economic loss due to discarded seedlings, plantation failures, and interplanting needs are estimated at about $220,000. Recommendations for avoiding future losses are given.

Acknowledgement is made of the helpful assistance of personnel of the Sumter National Forest in collecting and providing field survival data.

CONTENTS

INTRODUCTION

A loblolly pine seedling survival problem of widespread distribution and considerable magnitude was reported in early spring 1983 on the Sumter, Chattahoochee, and Oconee National Forests in South Carolina and Georgia. A combined total of approximately 6,400 acres was scheduled for planting with loblolly pine in 1983, which required approximately 3.6 million seedlings. This makes the potential impact of poor plantation survival great.

Evaluations of stored and newly planted loblolly pine seedlings were needed to determine the causes, distribution, and potential economic losses on 10 Ranger Districts planting loblolly pine on these 3 National Forests.

The Problem

Damaged loblolly pine seedlings were first detected in early February 1983 by personnel on the Long Cane Ranger District, Sumter National Forest, South Carolina. Previously unopened bags containing seedlings lifted on December 29, 1982 had been removed from cold storage for outplanting. Seedlings were found to have extensively damaged roots. Additional bags from this lifting date and from liftings on January 13, 1983 were removed and found to contain seedlings similarly damaged. Visits to plantations established with these seedlings during the previous month showed that substantial mortality had already occurred. Subsequent inquiries of other Ranger Districts and National Forests revealed the problem was present elsewhere.

Loblolly pine seedlings used in regeneration efforts on the Sumter, Chattahoochee, and Oconee National Forests are of two seed sources--South Carolina piedmont (number 39-1-131-1-81-01) and Georgia piedmont (number 10-1-131-1-80-01). Seedlings are grown by the U.S. Forest Service at the W. W. Ashe Nursery, Brooklyn, Miss., packed in K-P bags after coating roots with clay slurry to prevent desiccation, shipped in refrigerated vans, and stored refrigerated at the Ranger District until needed.

On the Long Cane District, seedlings lifted from the Ashe Nursery and stored refrigerated for 3 to 5 weeks were deteriorating, and plantations established with seedlings stored for shorter periods were experiencing poor survival.

The results of the laboratory diagnoses and evaluations of stored seedlings and newly established outplantings are presented here.

LABORATORY DIAGNOSES

Methods

Damage was described after washing soil, clay slurry packing material, and other debris from tree roots and carefully examining damaged and healthy-appearing seedlings from cold storage and newly established plantations on the Tyger, Enoree, Long Cane, and Edgefield Ranger Districts, Sumter National

Forest. Seedlings had been lifted from the W. W. Ashe Nursery on December 29, 1982 and January 13, 1983. Storage periods were 5 and 3 weeks for stored seedlings, but less for planted trees. Some plantations were examined that were planted with seedlings on the day of their receipt.

Diagnoses were centered on root disease, because gross mechanical and handling damage, insect injury, and seedling top disorders were absent. Damaged roots were cultured on two media. PARP medium (Kannwischer and Mitchell, 1981) was used as a selective medium to detect *Pythium* and *Phytophthora* spp., and acidified PDA medium (extract of 200g of potatoes boiled in 500 ml of distilled water and squeezed through double cheesecloth + distilled water to 1,000 ml + 20g dextrose + 17g agar; adjusted to pH 4.7 with 50% lactic acid) was used as a broad spectrum medium to detect other potential fungus pathogens. Damaged root pieces were cultured on PARP medium after washing in running tap water and blotting. Root pieces cultured on acidified PDA were surface disinfected with a 10% clorox soak for 2 minutes, followed by blotting.

Results

The predominant symptom on damaged seedlings was a water-soaked, mushy deterioration of the root cortex. Pulling roots resulted in a sloughing of the cortex, leaving the bare, woody tissues. The lower 1/2 to 1/3 of the tap root and the end portions of larger laterals were most often affected, but some roots had patches of mushy root cortex surrounded by apparently healthy tissue. Excepting this symptom, seedlings had a good overall appearance. Tops were green and vigorous, most had a firm "winter" bud, and the root system was well developed, if somewhat deficient in feeder roots and mycorrhizae. In some cases, the seedling tops were judged too large for the root system.

A few seedlings (less than 5% of all seedlings examined) had corky proliferation of the cortex of the main upper laterals and upper tap root, characteristic of infection by the charcoal root rot fungus, *Macrophomina phaseolina.* Some of these seedlings also had the mushy root symptom, but charcoal root symptoms alone were very infrequently found.

Isolations onto PARP medium yielded no pathogenic fungi. *Macrophomina phaseolina* was recovered from root cortex with the corky proliferation, but no pathogenic fungi were recovered from mushy roots.

The extremely low incidence of charcoal rot symptoms and the lack of pathogens associated with the mushy root symptom indicated that the root problem was not due to infection by root disease fungi.

EVALUATION OF STORED SEEDLINGS

Evaluations of stored seedlings were conducted to determine the condition of seedlings lifted at different times and kept in storage, the influence of continued storage on the condition of seedlings, and the survival potential of damaged seedlings.

Methods

Seedling condition in storage.--Previously unopened seedling bags stored at the Long Cane Ranger District, Sumter National Forest, were transported in a covered vehicle to a laboratory and carefully examined. The time from removal from the District to laboratory cold storage was 3 hours, and outside temperatures were about 40°F. The seedlings had been lifted from the nursery on December 29, 1982 and January 13, 1983, and were examined on February 9, 1983 - a storage period of 6 weeks for December 29, 1982-lifted trees and about 4 weeks for January 13, 1983-lifted trees.

Bags were sampled by removing bundles of approximately 50 trees from different parts of the bag. A minimum of 250 trees were evaluated from each bag. Exposure of seedlings to room temperature was kept to a minimum. Seedlings were carefully examined after washing to remove soil and clay slurry packing material. They were tallied according to four classes:

1. Healthy - no apparent damage.
2. Greater than 50 percent of root system damaged - cause unknown.
3. Less than 50 percent of root system damaged - cause unknown.
4. Other diagnosed damage.

Additional damage assessment was done on seedlings from these and later lifting dates from a number of other storage locations (Ranger Districts). These are presented in Table 1. The approximate proportion of damaged trees was estimated after sampling similar to that described earlier.

Influence of additional storage on seedling condition.--The influence of longer storage was evaluated on January 13, 1983-lifted seedlings by repeating the root system damage distribution on March 10, 1983. This made the total storage period 8 weeks for these seedlings. During the extended storage period, the seedling bag was opened and the seedlings moistened periodically to prevent excessive drying.

Survival potential of damaged seedlings.--Seedlings with more than 50 percent of their root system damaged were judged to have no chance of surviving. However, many seedlings were not damaged to that extent. An evaluation of the survival potential of seedlings with less than 50 percent of their root system damaged (class 3 seedlings; see Methods - Seedling condition in storage) was needed.

Seventy-five class 3 seedlings from the January 13, 1983-lifted bags were planted in 8" x 10" plastic pots (3 seedlings per pot) immediately after the February 9, 1983 seedling-condition-in-storage evaluation. The potting medium (1:1 mixture of peat moss and vermiculite) was kept moist and the seedlings grown in a heated greenhouse under temperatures favorable for growth. Twelve seedlings without any apparent root damage were similarly potted and served as controls.

Results

Seedling condition in storage.--The number of seedlings from storage at the Long Cane Ranger District, Sumter National Forest, with different levels of root damage for two different nursery lifting dates (storage periods), is

Table 1.--Storage periods for seedlings examined for root damage, by National Forest and Ranger District.

Location	Nursery Lifting Date	Observation Date	Approximate Storage Period (weeks)
Sumter N.F.			
Tyger R.D.	12/29/82	2/8/83	6
Enoree R.D.	12/29/82	2/8/83	6
	1/13/83	2/8/83	4
Long Cane R.D.	12/29/83	2/8/83	6*
	1/13/83	2/8/83	4*
	1/13/83	3/10/83	8*
Edgefield R.D.	12/29/82	3/4/83	7
	1/13/83	3/4/83	5
	2/18/83	3/4/83	2
	3/1/83	3/4/83	0.5
Chattahoochee N.F.			
Brasstown R.D.	12/29/82	3/16/83	9

* Quantitatively evaluated for seedling condition in storage and influence of additional storage on seedling condition.

summarized in Table 2. Nearly all of the seedlings stored for 6 weeks were damaged, with 90 percent showing the mushy root symptom. Two-thirds of these were in the most heavily damaged class. Only 7 percent were without root damage. The seedlings lifted later (stored 4 weeks) were in much better condition, but nearly one-third of these showed the mushy root symptom.

The results of evaluations of seedlings stored at other locations for varying periods were similar. Seedling bags stored from earlier liftings (more than 2 weeks of storage) had the highest levels of root damage and did not contain enough healthy seedlings to attempt outplanting. Seedlings lifted in mid-February (2 weeks of storage) and early March (less than 1 week of storage) were free of the mushy root symptom. Three to 5 percent of the seedlings from each lifting date had damage resembling that caused by the charcoal rot fungus.

Influence of additional storage on seedling condition.--An additional 4 weeks of cold storage resulted in marked deterioration of seedlings lifted on January 13, 1983 (Table 3). The percentage of seedlings with the mushy root symptom more than doubled in the additional storage period, with the most severely damaged class increasing 6-fold.

Even though seedlings lifted in mid-January deteriorated during 8 weeks of cold storage, they were in better condition than seedlings lifted in late December and stored for a shorter period of time. January liftings stored for 8 weeks had twice as many healthy seedlings and 17 percent fewer seedlings in the severely damaged category as December-liftings stored for 6 weeks (Table 3).

No reports of root deterioration in seedlings lifted in February or March and stored were made by personnel of the Chattahoochee, Oconee, or Sumter National Forests after these evaluations were conducted.

Survival potential of damaged seedlings.--Greenhouse survival of seedlings with less than 50 pecent of the root system damaged after one month was 87 percent, with no mortality in the control seedlings. No mortality occurred after this period, but there were differences in the time required for initiation of shoot elongation. Of the seedlings remaining alive, 10 percent had elongating shoots 4 weeks after planting, 89 percent after 6 weeks, and 96 percent after 10 weeks. Three seedlings had not initiated shoot growth 12 weeks after planting under conditions favorable for growth.

Examination of root systems of some growing seedlings 10 weeks after planting revealed that the mushy root symptom had not progressed and that new roots had proliferated from the tap root above the affected areas.

EVALUATIONS OF OUTPLANTINGS

Methods

Outplantings established with seedlings lifted at different times and stored for varying periods of time were evaluated to determine survival, patterns of mortality, the condition of roots of living trees, and the possible influence of other factors (site quality, site preparation methods, planting crews) on the problem.

Table 2.--Percentage distribution of seedlings by damage class and nursery lifting date, Long Cane Ranger District, Sumter National Forest, South Carolina, February 1983. Seedlot #39-1-131-1-81-01, South Carolina piedmont loblolly.

Lifting Date	Storage Period (weeks)	Healthy	<50% of[1] Root System Symptomatic	>50% of[2] Root System Symptomatic	Charcoal[3] Rot	Total No. of Seedlings Evaluated
12/29/82	6	7	30	60	3	250
1/13/83	4	62	25	8	5	523

1/ Lightly damaged seedlings; field survival potential unknown.

2/ Severely damaged seedlings; field survival impossible.

3/ Root disease caused by Macrophomina phaseolina. Most infections severe enough to depress growth or kill seedling when outplanted.

Table 3.--Percentage distribution of seedlings by damage class for different lifting dates and storage periods, Long Cane Ranger District, Sumter National Forest, South Carolina, 1983. Seedlot #39-1-131-1-81-01, South Carolina piedmont loblolly.

			Condition				
Lifting Date	Observation Date	Storage Period (weeks)	Healthy	<50% of Root System Symptomatic [1]	>50% of Root System Symptomatic [2]	Charcoal Rot [3]	Total No. of Seedlings Evaluated
12/29/82	2/10/83	6	7	30	60	3	250
1/13/83 [4]	2/10/83	4	62	25	8	5	523
1/13/83 [4]	3/10/83	8	13	30	50	7	261

1/ Lightly damaged seedlings.

2/ Severely damaged seedlings; field survival impossible.

3/ Root disease caused by *Macrophomina phaseolina*. Most infections severe enough to depress growth or kill seedling when outplanted.

4/ Same seedling bag kept at 33°F in walk-in cooler and lightly moistened periodically.

Plantations established in March and April 1983 were examined 1 to 3 months after establishment. The following variables were considered when choosing stands for evaluation:

lifting date of seedlings
storage conditions
length of storage of seedlings
location of plantation
site preparation method
site preparation success
harshness of site (environmental extremes)
planting crew (contract or USFS)

Efforts were made to evaluate widely separated plantations established with seedlings stored, handled, and planted under the full range of conditions prevailing on different Ranger Districts. The locations and number of plantations examined, and the month of lifting of the seedlings used are summarized in Table 4. Some uncertainty over lifting dates of seedlings exists. This is due to differences in recordkeeping between Districts, use of seedlings from several lifting dates in many plantations, and trading of seedlings between Districts.

The plantation was thoroughly traversed, covering the range of environmental conditions present. Periodically, healthy appearing and dying seedlings were dug up and carefully examined for pest- or man-caused damage, improper planting, and other disorders. Survival was characterized generally, and pertinent data were recorded (seedling lifting date, planting date, site preparation, planting crew). Additionally, a quantitative evaluation of survival was done by District personnel on the Tyger, Enoree, Long Cane, and Edgefield Ranger Districts of the Sumter National Forest. Results of June survival counts are discussed.

Results

Mortality occurred on all Districts, on various sites prepared with different methods, and in outplantings established with seedlings having different lifting dates and planted by different contractors and U.S. Forest Service planting crews. However, damage was not uniformly severe within or between plantations. Dead seedlings occurred in groups, but patterns were not evident with respect to microsite (dead seedlings were not confined to burned, bare, dry, or compacted soil).

Isolated instances of severe root pruning or poor seedling handling practices by some planting crews did occur, but in nearly all cases, seedling handling by field crews was proper. Further, site conditions were exceptionally good for tree planting in the spring of 1983, with abundant soil moisture and well-distributed rainfall. It was apparent that mortality was due primarily to the root deterioration seen in earlier evaluations of stored seedlings.

General observations of survival, with respect to lifting date and storage period, paralleled the results of earlier stored seedling evaluations; i.e., the earlier the seedlings were lifted and the longer they were stored (> 2 weeks), the more root deterioration was present and the lower the plantation

Table 4.--Location and number of plantations evaluated for survival problems on the Sumter N.F., South Carolina, and the Chattahoochee N.F., Georgia, 1983.

Location	Number of Plantations Evaluated	Months of Lifting Represented
Sumter N.F.		
Edgefield R.D.	3	Dec., Jan.
Long Cane R.D.	3	"
Enoree R.D.	3	"
Chattahoochee N.F.		
Armuchee R.D.	5	Dec., probably Jan., Feb.
Brasstown R.D.	1	Jan.
Chattooga R.D.	4	Dec., probably Jan., Feb.
Tallulah, R.D.	3	Dec., Jan., Feb.
Total	22	

survival. Though no evaluations were conducted on the Oconee National Forest, Georgia, similar survival problems and observations of root deterioration and lack of pest damage were made by others (S. J. Rowan, personal communication).

Data on June survival of stands planted with trees of various lifting dates are difficult to interpret. Survival on the Edgefield Ranger District, Sumter National Forest, was generally in keeping with the field observations made by the author earlier in the spring (Figure 1). Survival of December 29, 1982-lifted trees precipitously declined after relatively short storage periods. No January-lifted trees were planted, but February- and March-lifted trees survived better, even after extended storage. Lower survival in March-lifted trees stored for 2 weeks represents observations made in only one plantation.

Survival of loblolly seedlings planted Forest-wide were generally in keeping with the author's storage and field observations, but the decline in field survival of December-lifted seedlings seemed to cease after 4 weeks of storage, rather than declining further (Figure 2). Plantings are established over periods ranging from a few days to several weeks. This results in some plantations containing seedlings stored for variable periods of time, or even with seedlings of two or more lifting dates. Survival reports of entire plantations would, in those situations, represent a composite or pooled survival of potentially highly variable plots.

Further, sampling methods could influence survival reports. These data were from circular microplots of 10-20 seedlings spaced along a compass line. While this design effectively samples for stocked plots in the plantation, it is not as effective for sampling the patchy and highly variable survival observed by the author. A series of continuous transects, where a corridor of seedlings are evaluated, may be better for determining losses where they have patchy distribution.

ECONOMIC LOSS

Methods

Several components are included in calculation of economic loss due to seedling deterioration. These include the value of seedlings discarded because of poor quality, value of site preparation and seedling planting loss due to complete plantation failure, and value of site preparation and seedling planting loss due to partial plantation failure. The assumptions included in each category of loss and the computations are:

Seedlings discarded:

Value of seedlings = \$50/1,000
Loss = value of seedlings x number discarded

Complete and partial plantation failure:

Value of site preparation = \$100/acre
Value of seedlings + planting = \$50/acre
Value of plantation establishment = \$150/acre

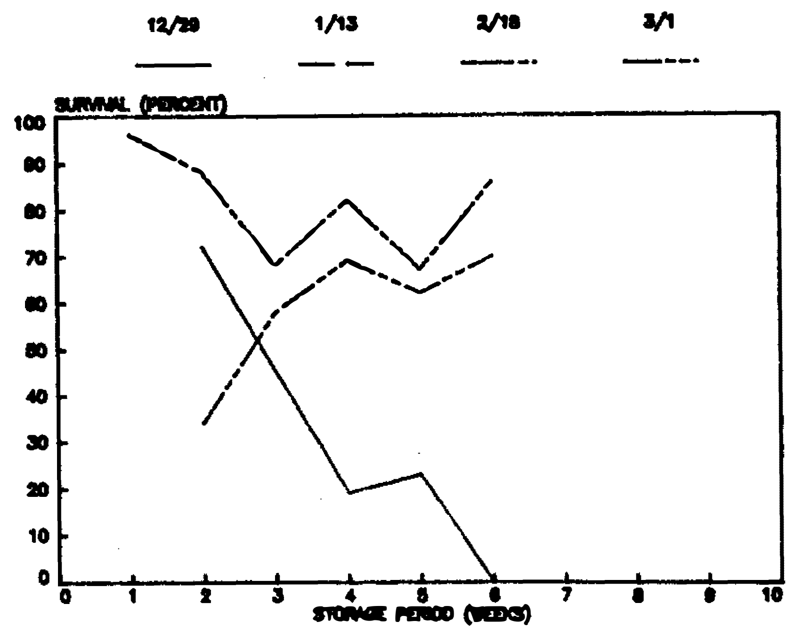

Figure 1. June survival for seedlings lifted on different dates and stored for varying periods. Edgefield RD, Sumter NF, 1983.

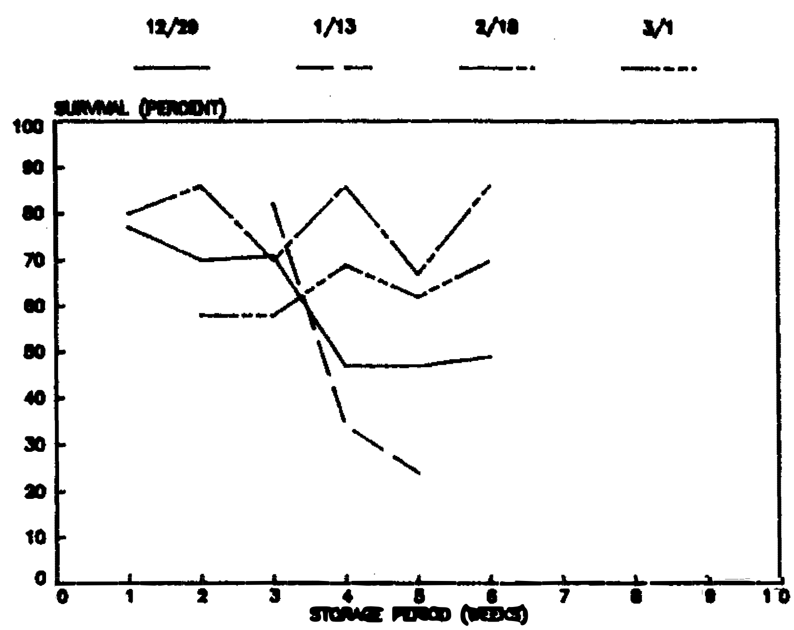

Figure 2. June survival for seedlings lifted on different dates and stored for varying periods. All RD combined, Sumter NF, 1983.

Data from Sumter National Forest Ranger Districts show that only December- and January-lifted trees had severe survival problems. Survival ranged from 88 to 0 percent for 29 plantations established with these seedlings. Twenty-one (72%) had less than 50 percent survival. Assumptions used for calculation are that half of all acres planted with December- and January-lifted trees will require complete replanting (loss of $150/acre establishment cost) and an additional 25 percent of all acres will require significant interplanting efforts (loss of $75/acre establishment cost). The remaining acres have adequate survival and stocking.

Acres planted with December- and January-lifted seedlings:

Sumter National Forest -	1,000 acres
Chattahoochee-Oconee National Forests -	1,100 acres
	2,100 acres

Results

Seedlings discarded.--The Sumter and Chattahoochee-Oconee National Forests discarded a total of 441,000 seedlings. Dollars lost equal $22,050.

Complete and partial plantation failure.--About 1,100 acres will require complete replanting. Dollars lost equal $157,500. About 525 acres will require significant interplanting. Dollars lost equal $39,375.

The total dollars lost to the seedling deterioration problem on the Sumter and Chattahoochee-Oconee National Forests is estimated at $218,925.

DISCUSSION AND SUMMARY

It is clear that the mushy root symptom was not due to pathogenic fungi or other commonly occurring root pests. Its cause is physiological, but the specific factors responsible cannot be determined with certainty. However, most of the results of evaluations reported here are consistent with those made by others investigating seedling performance when seedlings are lifted without achieving full physiological dormancy.

Dormancy relationships have only recently been investigated for loblolly pine. Initiation of root growth is thought to be closely linked with physiological dormancy in forest seedlings. In a review of root growth potential (a measure of dormancy fulfillment), Ritchie and Dunlap (1980) identify a dormancy cycle consisting of dormancy induction, deepening, true dormancy, and quiescence. This cycle is initiated in response to shortening photoperiod and, to some degree, declining temperature.

Before seedlings may resume normal root and shoot growth, a minimum chilling requirement must be met (Ritchie and Dunlap, 1980). Garber and Mexal (1980) state that about 7 weeks exposure to natural conditions prevailing during November and December is needed to fully satisfy the chilling requirement of loblolly pine. This period may vary with genotype (seed sources [Beineke and Perry, 1965]) and the location where seedlings are grown (climate). Garber and Mexal probably conducted studies in Arkansas, where their companies' research facilities and nursery are located.

Once chilling requirements are met, seedlings may be stored for long periods (2 months) without marked decrease in survival (Garber and Mexal, 1980; Rhea, 1977; Ritchie and Dunlap, 1980). However, accumulating chilling hours and inferring dormancy may not be an accurate reflection of dormancy, because interruption of cool, dormancy-inducing weather by periods of higher temperature can negate the chilling response in some conifers. Some workers have suggested that nurseries located in areas where winters have periodic unseasonably warm spells may not be able to produce fully dormant, storable seedlings (Ritchie and Dunlap, 1980).

Results of studies in Virginia loblolly nurseries caused Dierauf to speculate that differences in dormancy from year to year may influence the storability of early-lifted seedlings (1978). In one of two test years, survival was satisfactory for both early-lifted seedlings planted immediately and those stored for two weeks. In the other test year, substantial differences in survival were seen, with stored seedlings surviving much more poorly than immediately planted seedlings (Dierauf, 1976).

Nursery cultural practices may affect the length of chilling requirements. Root pruning seedlings during dormancy induction and deepening affects plant-water relations and the duration of chilling requirements, as does withholding irrigation in late summer (Ritchie and Dunlap, 1980). Fertilization with nitrogen late in the growing season has been observed to result in seedling storage and survival problems in some southern nurseries (D. South, personal communication).

Conversations with the W. W. Ashe Nursery manager revealed that nitrogen fertilizer had been applied as late as October 1982, and that the fall and winter at the nursery were uncharacteristically warm and wet, with frequent heavy rains.

Several factors considered together suggest that dormancy relations had a significant role in the storage and survival problems experienced on the Sumter, Chattahoochee, and Oconee National Forests in 1983. Those factors are;

1. the lack of pest-caused damage on stored and newly planted seedlings;

2. the presence of the condition on seedlings at widely separated locations in storage and the field, in spite of proper handling and storage at all levels;

3. the pattern of mortality, with respect to seedling lifting date and storage period;

4. the absence of the problem from the coastal loblolly seed source inspite of being grown in the same locality in the nursery and receiving identical cultural treatments as the affected piedmont source;

5. climatic conditions and cultural practices at the W. W. Ashe Nursery; and

6. known dormancy relationships for loblolly pine and other conifers.

RECOMMENDATIONS

In the absence of research data delineating dormancy relationships for different loblolly pine seed sources grown at the W. W. Ashe Nursery, the following are suggested for avoiding and managing future occurrences of this problem.

1. Consider contracting with state-owned forest tree nurseries in close proximity to National Forests in the eastern and northern parts of R-8 to minimize shipping and storage time, <u>or</u>

2. Consider establishing a federal nursery in the southern Appalachian area to provide seedlings for National Forests nearby.

3. Avoid late-season nitrogen fertilization of Georgia and South Carolina piedmont loblolly seedlings at the W. W. Ashe Nursery.

4. Consider methods to induce water stress in seedbeds at the W. W. Ashe Nursery (e.g., undercutting, managing irrigation) to promote induction of seedling dormancy.

5. Consider instituting a consistent system of recordkeeping and seedling inventory control at the District level to ensure that lifting and storage information can be tied to a specific planting site.

6. Consider imprinting seedling bags with "PLANT BY <u>(date)</u>" at the nursery to ensure minimum storage at the District.

7. While the low level of charcoal rot found in these seedlings will not, by itself, cause plantation failures, it does indicate infestation of W. W. Ashe Nursery soil. These symptoms developed even though climatic conditions during the growing season were very unfavorable for charcoal rot to develop. This indicates future, more severe charcoal rot may occur, if corrective measures are not taken. Soil fumigation with registered rates of MC-33 is recommended before pine crops are grown in infected areas.

Recommendations for future research should focus on determining the factors controlling dormancy at the W. W. Ashe Nursery with the goal of replacing current calendar date lifting guidelines with more biologically sensitive and flexible guidelines. Questions to be considered may include:

1. Is there a dormancy requirement for loblolly pine seed sources used by the National Forests in R-8?

2. If 1. exists, how is it altered by different cultural practices; e.g., undercutting, irrigation management, and fertilization?

3. If 1. exists, how do different climatic conditions influence it?

4. Is there a method by which effective storage periods can be determined for different lifting dates from year to year?

5. Can dormancy be induced through the application of growth-inhibiting substances at a specified time prior to lifting?

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Forest Pest Management
Asheville Field Office

Report #83-1-22
September 1983

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